

# Preliminary Geologic Map of the Point Sur 30' x 60' Quadrangle, California

**Version 1.0**

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## Introduction

The Point Sur 30' x 60' quadrangle covers approximately 5,000 km<sup>2</sup> of northern Monterey and southwestern San Benito Counties, California. The area of this map extends about 80 km east-west from the coast at Point Sur to the Bitterwater Valley along the San Andreas Fault zone. It extends about 55 km north-south from Carmel Highlands to Lucia along the coast and from Soledad to San Ardo in the Salinas Valley. The Point Sur 30'x60' includes much of the rugged Big Sur coastline, National Forest and wilderness in the Santa Lucia Mountains, and some of the richest farmland in the world in the Salinas Valley. The relief in the quadrangle ranges from about a thousand meters below sea level in submarine canyons to more than 1700 meters above sea level at Junipero Serra Peak in the Santa Lucia Mountains. Residents and visitors are subject to potential hazards from earthquakes, debris flows and other landslides, floods, wildfires, and subsidence from ground water and petroleum withdrawal. Coastal areas are exposed to erosion by storm and tsunami waves and landsliding. This geologic map is intended to illustrate the distribution of the rocks and surficial deposits of the area and their structural and stratigraphic relations to one another. It provides a regional geologic framework as an aid to better evaluations of the potential for hazard from active earth processes. As a digital product it includes some areas mapped in greater detail than others; however, it is not sufficiently detailed to serve as a basis for site-specific evaluations.

## Development of Geologic Map Database

The map has been compiled from many scientific studies in different parts of the quadrangle, and represents the work of many geologists. Compilation of the Point Sur 30' x 60' quadrangle builds on compilation by Lew Rosenberg for the Monterey County General Plan (Rosenberg, 2001). For that compilation, paper copies of existing geologic maps were scanned and converted into digital lines and polygons using Geographic Information System (GIS) software. In the compilation for Monterey County, Rosenberg selected the most detailed and accurate map of a particular area to digitize. One problem encountered in creating the seamless geologic map was that geology did not always match from areas mapped by one geologist to areas mapped by others. Reasons for the discrepancies include differences in mapping styles and emphasis on different geological hazards or resources. Some geologists have been concerned with mapping one aspect of the geology, crystalline bedrock for example, with less detail or concern in mapping other units. Other inconsistencies included different terminology in naming geologic units and faults, drafting errors, and accuracy issues. Although the source maps have been accurately digitized, mapping errors by the original authors still exist. Following the compilation for Monterey County, Rosenberg continued to update the GIS map with additional sources and detail, in some cases with support from the California Geological Survey (CGS). Rosenberg also worked with the National Park Service to prepare a GIS database of the region around Pinnacles National Monument, adding the San Benito County area of the Point Sur 30'x60' quadrangle to the previous map of Monterey County. The National Park Service also assisted by converted the previous GIS files from the Monterey County compilation into a more current geodatabase format (O'Meara, 2010). Lew was working toward a completed geologic map in the format used for CGS regional geologic maps when he became ill in 2010. He passed away in 2013. This map represents an attempt to honor Lew's legacy by completing the map he had so far along. Additional effort has gone into creating a single uniform nomenclature for the geologic units in the map area and incorporating new mapping published in the past few years.

## Sources of geologic mapping

The listing of sources of geologic mapping below includes geologic maps that were used by Rosenberg, (2001), and additional geologic maps included in this compilation.



**Figure 1.** Index map of 7.5 minute quadrangles within the Point Sur 30'x60' quadrangle. DEM from U.S. Geological Survey

**Bear Canyon:** Durham 1963, 1964, 1970; Dibblee 1971, 1974; Ross 1976; Seiders et al. 1983

**Big Sur:** Clark and Rosenberg 1999; Dibblee 1974; Hall 1991; Jackson 1977; Maddock 1960; Ross 1976; Wiebe 1966; Wills et al. 2001

**Carmel Valley:** Bechtel 1988; Clark et al. 1997; Clark and Rosenberg 1999; Cotton and Associates 1995; Dickinson unpub. mapping; Dibblee 1974; Dupre 1990, unpub. mapping; Kidder 2006, unpub. mapping; McKittrick 1987; Neel 1963; R.E. Johnson & Associates 1985; Rosenberg 1993, 1998; Ross 1976; Seiders et al. 1983; Wiebe 1966

**Chews Ridge:** Dibblee 1971, 1974; Dickinson 1965, unpub. mapping; Durham 1970; Fiedler 1944; Kidder 2006, unpub; McKittrick 1987; Rosenberg unpub. 2008; Ross 1976; Seiders et al. 1983; Wiebe 1966

**Cone Peak:** Dibblee 1971, Hall 1991; Ross 1976; Seiders et al. 1983; Taliaferro, 1958; Wills et al. 2001

**Cosio Knob:** Dibblee 1971; Durham 1963; 1964; Klaus 1999; Weidman 1959

**Espinosa Canyon:** Dibblee 1971, 1974; Dohrenwend 1975; Durham 1963, 1964, 1970; Hart 1985

**Greenfield:** Dibblee 1971; Dohrenwend 1975; Durham 1963, 1964, 1970; Ross 1972; Taylor and Sweetkind, 2014; Tinsley 1975

**Junipero Serra Peak:** Dibblee 1971, 1974; Dickinson 1965; Durham 1963, 1964, 1970; Seiders et al. 1983; Snetsinger 1962; Taylor and Sweetkind, 2014.

**Lopez Point:** Dibblee 1971; Hall 1991; Reneau 1979; Ross 1976; Seiders et al. 1983; Wills et al. 2001

**Mount Carmel:** Clark et al. 1997; Clark and Rosenberg 1999; Cleary Consultants 1994; Dibblee 1974; Dupre, 1990; Rosenberg 1993; Rosenberg, 1999; Ross 1976; Weibe 1966,

**North Chalone Peak:** Dibblee 1971, 1974; Dohrenwend 1975; Durham 1963, 1964, 1970; Matthews 1973; Ross 1972; Tinsley 1975

**Palo Escrito Peak:** Dibblee 1971, 1974; Dohrenwend 1975; Durham 1963, 1964, 1970; Kidder 2006, unpub. mapping; Ross 1976; Tinsley 1975

**Paraiso Springs:** Dibblee 1971, 1974; Dohrenwend 1975; Durham 1963, 1964, 1970; Kidder 2006, unpub. mapping; Ross 1976; Taylor and Sweetkind, 2014; Tinsley 1975; Seiders et al. 1983; Snetsinger 1962

**Partington Ridge:** Compton 1960; Dibblee 1974; Hall 1991; Reiche 1934, 1937; Ross 1976; Seiders et al. 1983; Weibe 1966; Wills et al. 2001

**Pinalito Canyon:** Dibblee 1971; Durham 1964; Dohrenwend 1975; Ross 1972

**Pfeiffer Point:** Dibblee 1974; Hall 1991; Ross 1976; Wills et al. 2001

**Point Sur:** Dibblee 1974; Hall 1991; Ross 1976; Wills et al. 2001

**Rana Creek:** Dibblee 1974; Dickinson unpub. mapping; Dupre 1990, unpub. mapping; Durham 1970; Kidder 2006, unpub; McKittrick 1987; Rosenberg unpub. 2008; Ross 1976; Seiders et al. 1983; Tinsley 1975

**Reliz Canyon:** Dibblee 1971, 1974; Durham 1963, 1964, 1970; Ross 1976; Seiders et al. 1983; Taylor and Sweetkind, 2014.

**San Lucas:** Dibblee 1971, 1974; Dohrenwend 1975 Durham 1963, 1964, 1970; Ross 1972 Tinsley 1975

**Soberanes Point:** Clark and Rosenberg 1999; Clark et al. 1997; Dibblee 1974; Ross 1976 Wiebe 1966; Wills et al. 2001

**Soledad:** Dibblee 1971, 1974; Durham 1963, 1964, 1970; Dohrenwend 1975; Matthews 1973; Ross 1972; Tinsley 1975,

**Sycamore Flat:** Dibblee 1971, 1974, Dohrenwend 1975; Durham 1963, 1964, 1970; Fiedler 1944; Kidder 2006, unpub.mapping; Ross 1976; Seiders et al. 1983; Snetsinger 1962; Taylor and Sweetkind, 2014; Tinsley 1975.

**Tassajara Hot Springs:** Dibblee 1971, 1974; Dickinson 1965; Reiche 1934; Ross 1976; Seiders et al. 1983; Wiebe 1966; Wills et al. 2001

**Thompson Canyon:** Dibblee 1971, 1974; Dohrenwend 1975; Durham 1963, 1964, 1970; Taylor and Sweetkind, 2014; Tinsley 1975.

**Topo Valley:** Dibblee 1971; Dohrenwend 1975; Matthews 1973; Ross 1976; Graymer et al. in prep. 2016

**Ventana Cones:** Clark and Rosenberg 1999; Dibblee 1974; Dickinson 1965; Ross 1976; Seiders et al. 1983; Weibe 1966

## **Regional Geology**

[The following description is modified from Rosenberg (2001)]

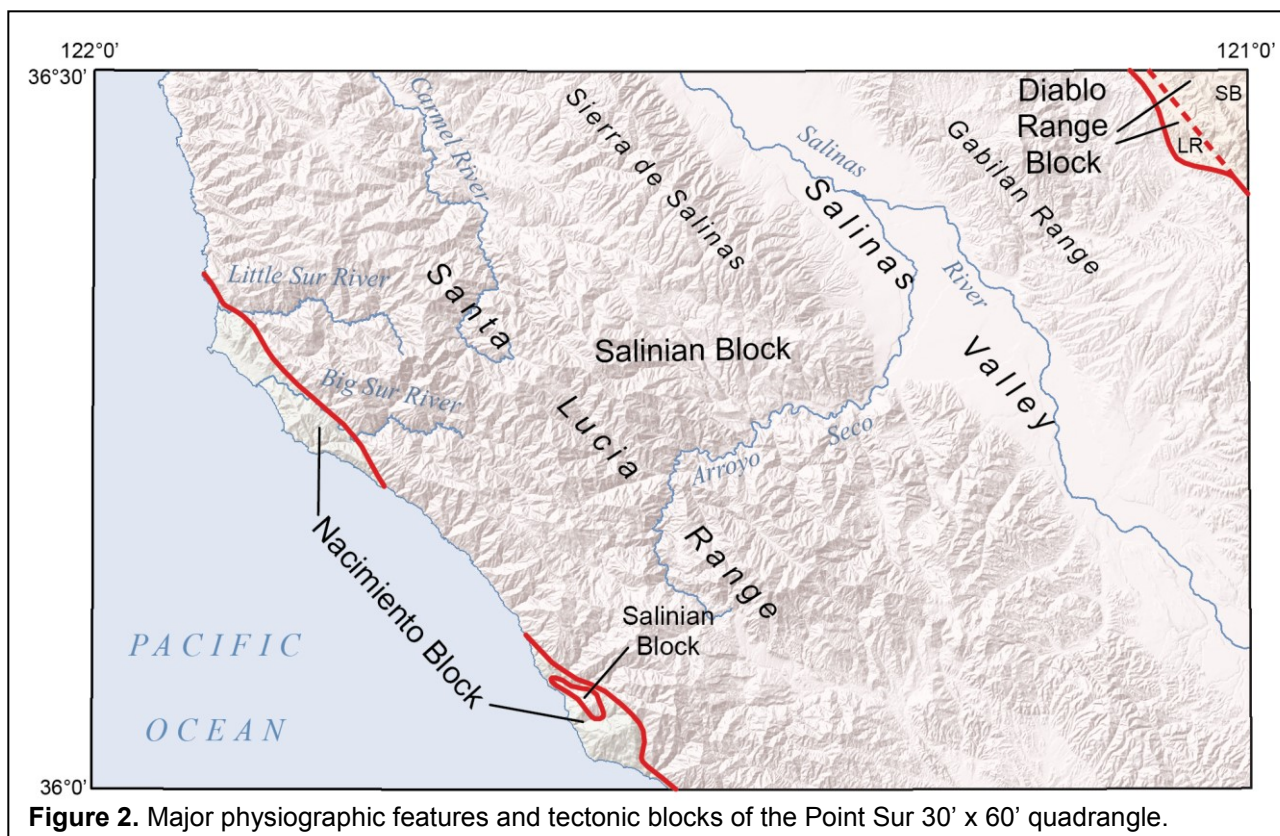
The Point Sur 30' x 60' Quadrangle lies entirely within the California Coast Ranges physiographic province and is underlain by four fundamentally different basement terranes of Mesozoic age: the Franciscan Complex, the Great Valley complex, the Schist of Sierra de Salinas, and the Salinian complex. The Salinian complex and the Schist of the Sierra de Salinas comprise the basement of the Salinian block, named for the city of Salinas, a northward-transported tectonic block bounded by the San Andreas Fault to the east and the Sur/Nacimiento Faults to the west. The basement of the Diablo Range block, east of the San Andreas and of the Nacimiento block west of the Sur/Nacimiento Faults are composed of Franciscan Complex and Great Valley Complex. The Salinian block is totally devoid of Franciscan and related rocks, whereas the Diablo and Nacimiento blocks lack granitic intrusive rocks. All of the basement blocks are covered in part by Cretaceous and Cenozoic sedimentary rocks, the distribution of which reflect varying amounts of movement on faults of the San Andreas system. Tectonic activity associated with the faults bounding these structural blocks formed the Santa Lucia Range, Sierra de Salinas, Gabilan Range, and the Diablo Range (Figure 2).

### **Franciscan Complex**

This complex consists mainly of oceanic crustal material and sedimentary rocks of Late Jurassic and Cretaceous age that were transported on a moving tectonic plate toward North America. At the North American plate boundary, these oceanic materials were tectonically interleaved with volcanic rocks and sediments from the continent along a subduction zone. During Mesozoic time the rocks were partially metamorphosed under high-pressure and low-temperature conditions and accreted to North America.

### **Great Valley Complex**

Rocks of the Franciscan Complex are in tectonic contact with the Great Valley complex, Jurassic Coast Range ophiolite and Jurassic-Cretaceous marine sedimentary rocks of the Great Valley Group/Sequence, mainly sandstone, southwest of the Sur/Nacimiento Fault and northeast of the San Andreas Fault. The subduction margin thrust faulting that juxtaposed these Franciscan and Great Valley complex rocks probably occurred initially in mid-Jurassic and extended into late Cretaceous time. In the Diablo Range, the original subduction thrust relations have been greatly modified by Paleogene extensional detachment faulting and associated upper crustal thinning (Jayko et al., 1987; Harms et al., 1992).



**Figure 2.** Major physiographic features and tectonic blocks of the Point Sur 30' x 60' quadrangle.

## Salinian Complex

The Salinian block is composed of two basement complexes separated by a folded thrust fault. The hanging wall of the thrust is made up of the Salinian igneous-metamorphic complex, Cretaceous granitic rocks and screens and roof pendants of Cretaceous metamorphic rock of Paleozoic protolith. This northwest-trending basement terrane, which underlies most of the Point Sur 30'x60' Quadrangle, consists of granitic and older metamorphosed sedimentary rocks. The metasedimentary rocks are the oldest rocks in the region. Although no identifiable fossils have ever been found, the protoliths of these rocks are older than late Cretaceous and most probably are of Paleozoic age. They were originally thinly bedded sedimentary rocks that were laid down as marine beds on the continental shelf hundreds of miles to the south of their present location, probably west of the Mojave Desert in southern California, before being intruded by granitic magma and metamorphosed at high temperatures.

The granitic rocks were intruded largely in late Cretaceous time but include some plutons as old as Early Cretaceous in the central Santa Lucia Range (Bear Mountain - Paraiso Paloma area), having yielded radiometric ages of ~80-117 Ma (Clark et al., 1997; 2000; Kistler and Champion, 2001). The Salinian basement rocks were uplifted many miles very rapidly in late Cretaceous time and eroded before deposition of upper Upper Cretaceous (Maastrichtian) marine sedimentary rocks.

## Schist of Sierra de Salinas

The footwall of the folded thrust in the Salinian block is made up of the Schist of Sierra de Salinas, with both protolith and metamorphic age of Late Cretaceous, younger than the granitic rocks of

the Salinian complex. The detrital zircon age of the schist protolith, along with thermochronological studies, show that the Salinian complex was emplaced over a sedimentary sequence in Late Cretaceous time, and that (as mentioned above) both were rapidly uplifted and unroofed, a process largely complete in time for local deposition of latest Cretaceous (Maastrichtian) strata. Restoration of Neogene offset along the San Andreas Fault System restores the Schist of Sierra de Salinas to a position adjacent to the northwestern Mojave, suggesting that the protolith is probably forearc sedimentary rocks related to the Great Valley complex or possibly accreted sedimentary rocks related to the Franciscan complex.

## **Sedimentary units**

### **Salinian Block**

Latest Cretaceous (Maastrichtian) seas transgressed the Salinian complex basement of what is now the southern Santa Lucia Range and coarse-grained sediments were deposited in fan-delta and submarine-fan complexes along the margin of a steep basin bounded by normal faults (Grove, 1993). This marine transgression continued into early Tertiary time with Paleocene beds locally lying directly on the basement rocks.

Uplift during Eocene time produced a more widespread continental borderland that probably consisted of a series of isolated granitic highs, many of them islands, separated by deep basins. Within this borderland, granitic sands were shed from steep basin margins and accumulated as deep-sea fans (Graham, 1978). Deposition in the northern Santa Lucia basin continued into Oligocene time, producing alternating deep-marine and shallow-marine sequences.

During Oligocene time, crustal extension caused normal faulting that resulted in emergence of several large blocks of the Salinian basement, restriction of marine conditions, and local deposition of terrestrial beds adjacent to faults. Volcanism, indicative of extension, started at this time with basaltic flows and breccias of the lower Carmel Valley erupted about 27.0 Ma (Clark et al., 1984). Other volcanic centers related to the northward migration of the Mendocino Triple Junction and the initiation of the San Andreas Fault System developed locally in late Oligocene to early Miocene time along the northern Gabilan Range and to the southwest at the Pinnacles National Monument, where rhyolitic rocks are Ar/Ar dated at  $22.82 \pm 0.16$  and  $23.24 \pm 0.06$  Ma (Stanley et al., 2000). Right slip on the San Andreas Fault was initiated in central California after about 23 Ma and has resulted in the present separation of the Pinnacles volcanic rocks west of the fault from the correlative Neenach volcanic rocks to the east by over 300 km (195 miles) of total slip (Matthews, 1976).

During middle Miocene time, a major marine transgression began, and by late Miocene time, seas extended from the Monterey area to the Salinas basin and south. Shallow marine sands were laid down during transgression and lapped eastward onto granitic highs such as the Gabilan shelf. Rapid basinal deepening followed with thick accumulations at bathyal depths (500 to 1500 meters ~ 1,600 to 5,000 feet) of fine-grained sediment rich in diatoms. With deep burial and redistribution of silica from the diatoms, the lower part of the basinal section was cemented into hard siliceous mudstone and porcelanite, whereas the upper part of some sections, such as that east of Monterey, remained as punky impure diatomite. The resulting siliceous Monterey Formation is as thick as 3600 meters (12,000 feet) west of the Salinas Valley. Farther east, on the Gabilan shelf, the late Miocene was marked by deposition of shallow marine sandstone interbedded with lesser diatomaceous strata. In the Pinnacles area, the sandstone was deposited into an oblique-normal fault bounded basin that connected eastward to the southern San Joaquin basin (subsequently offset by movement along the San Andreas Fault).

By latest Miocene time, marine conditions became restricted and a shallow sea extended from the San Joaquin basin westward across the San Andreas Fault into the southeastern part of the region. Thick beds of sand, silt, and clay accumulated to form the Pancho Rico Formation that today caps the relatively low, southern part of the Gabilan Range, known informally as the Gabilan Mesa, east of King City and is the youngest marine formation in the region.

The Santa Lucia Range was initially uplifted in early Pliocene time. Streams draining southeastward from the range, as well as westward across the San Andreas Fault from the Diablo Range block, deposited coarse clastic sediments of the Paso Robles Formation in the upper Salinas Valley and across the Gabilan shelf. The range also underwent a large amount of WSW-ENE directed post-Monterey compression, as evidenced by tight folds, thrust/reverse faults, and steeply dipping fault-bounded slivers of Tertiary strata within the Salinian basement. Such compression is not in evidence in the Gabilan Range to the east, where compressional deformation is restricted to the rocks within and east of the San Andreas Fault Zone.

Concurrent with right slip on the San Andreas Fault, the Gabilan and Santa Lucia Ranges have been uplifted to their present elevations during Quaternary time, with most of this uplift probably occurring during the last 400,000 years (Page et al., 1998). Ongoing uplift of these central Coast Ranges is probably a result of a component of convergence between the Pacific and North America plates. A series of wave-cut, emergent marine terraces around the Monterey Peninsula and south along Highway 1 together with a series of fluvial terraces that flank the Carmel River resulted from uplift of the Santa Lucia Range in the last 1 million years. Based on studies of the coastal terraces, estimated rates of uplift vary from 0.18 mm/yr to as much as 0.32 mm/yr (Clark et al., 1997). Debris eroded from these uplifted ranges in Quaternary time has been deposited recently as gravel, sand, silt, and clay in the valleys and on the flood plains of the Salinas and Carmel Rivers. Active geologic processes are still modifying the land throughout the area. These processes include rivers eroding and depositing sediment, blowing sand forming coastal dunes, and landslides in the hillside areas.

## Diablo Range Block

The Diablo Range block has a post-basement depositional history distinct from that of the Salinian block, in part because for much of the Tertiary the two areas were not adjacent, having been juxtaposed by 300 km Miocene and younger offset on the San Andreas Fault. During Paleocene time, the Franciscan complex was not exposed, but the Great Valley complex was widely overlapped by marine sedimentary rocks along the margin of the San Joaquin Valley. In Eocene time, the Diablo Range block experienced widespread extension, thinning the Great Valley complex and bringing the Franciscan Complex to the surface locally, as evidenced by the presence of Franciscan detritus in Eocene strata overlying the Great Valley complex, and more locally deposition of Eocene strata on Franciscan basement. The Diablo Range block is largely devoid of Oligocene strata, probably the result of erosion/non-deposition reflected by multiple regional Miocene unconformities. Miocene deposition was marked by an early period of shallow marine sandstone (Temblor), followed by a deepening in early late Miocene time (Monterey, Reef Ridge), followed by a second period of shallow marine deposition (Santa Margarita, Jacalitos, Etchegoin, San Joaquin). The exact timing of these transitions varied from north to south within the block, resulting in overlapping ages for some units. The Miocene in the Diablo Range block was also marked by scattered, northward younging volcanic centers. In Pliocene time, regional uplift led to a period of erosion and nonmarine deposition which continues to the present time.

## Nacimiento Block

Although the Nacimiento block has a similar basement to the Diablo Range block, restoration of San Andreas Fault System offsets (described in detail below) reveal that prior to Miocene time the two structural blocks were separated by at least 450 km, reflecting the very widespread nature of the tectonostratigraphic domains along the North American margin in Mesozoic time. As a result, the two blocks have a distinct post-basement depositional history. North of the Transverse Ranges, the Nacimiento block is largely devoid of Paleocene and Eocene strata, suggesting an extended period of high-stand and erosion. The basement rocks show evidence of a period of large-scale extensional deformation, thinning of the Great Valley complex, and unroofing of the Franciscan Complex that must have occurred during this time, but the absence of Paleocene and Eocene strata precludes a closer estimate of the timing. The oldest post-basement strata, overlapping both basement complexes, are Oligocene volcanic and non-marine sedimentary rocks. In some places, non-marine deposition extended into, or did not start until early Miocene time, whereas in other places, shallow marine deposition began in Oligocene time. Throughout the block, the late early to early late Miocene was marked by deeper marine deposition of sandstone and siliceous shale, with thick volcanic strata deposited locally. In many parts of the Nacimiento block, including the map area, Miocene strata rest unconformably directly on basement, suggesting that earlier Tertiary deposition was localized in relatively small basins or that there was a period of limited or local uplift and erosional removal of Oligocene and early Miocene strata.

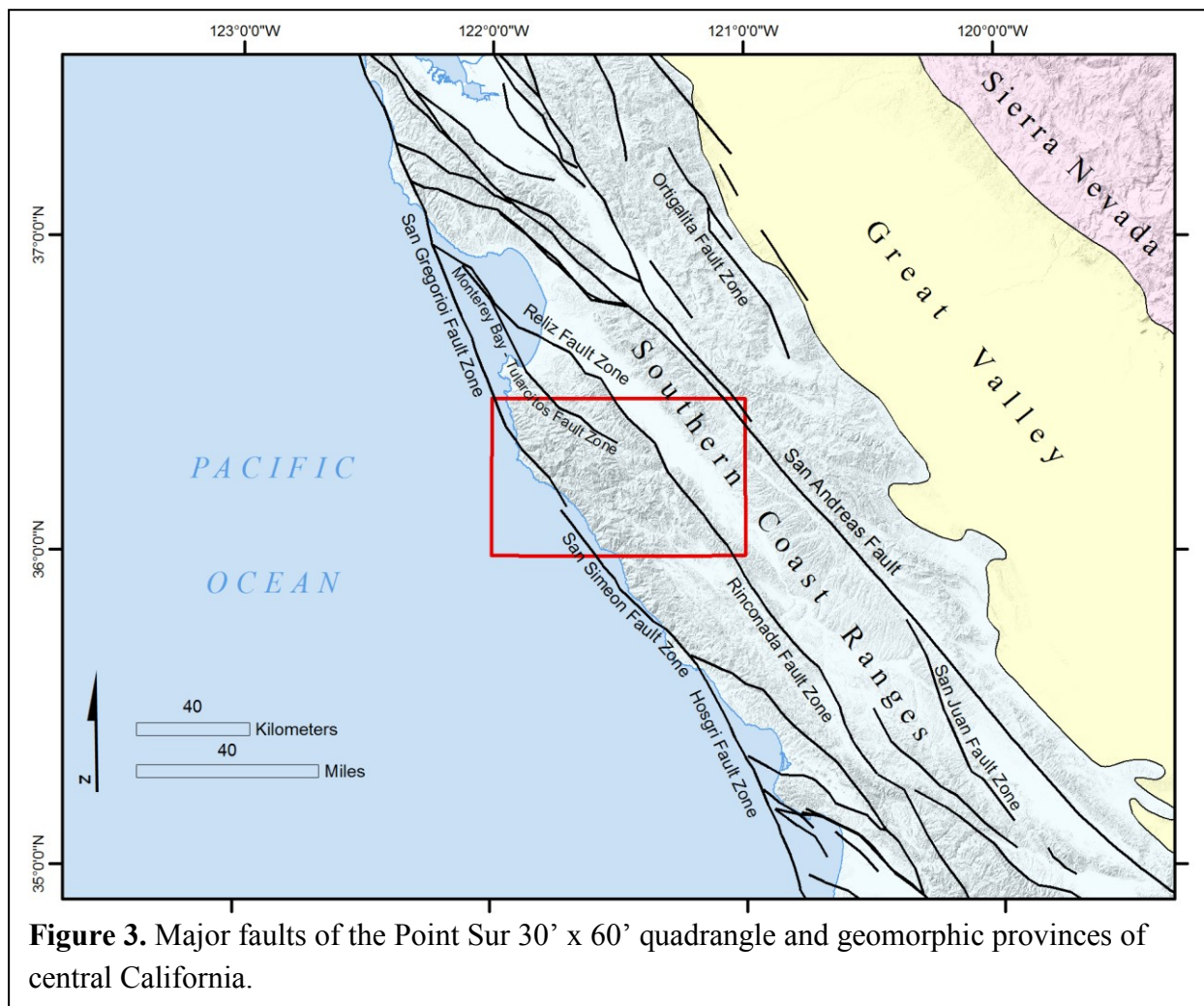
## Regional Structure

The Point Sur 30x60' Quadrangle lies across the broad boundary between the Pacific and North American tectonic plates, and the relative motion between these two plates, presently at the rate of about 4.8 cm/yr (De Mets et al., 2010), has produced most of the structural features of the region (Figure 3). These features include active strike-slip faults, near-vertical reverse faults, thrust faults, and related folds. Faults and folds generally trend north-northwestward and account for the similar trend of the mountain ranges and principal valleys.

## Faults

The active San Andreas and San Gregorio faults that bound the Salinian block on the northeast and southwest, respectively, dominate the present structural regime in the Point Sur 30x60' quadrangle. The San Andreas Fault has been active in the region after about 23 Ma, during which time it has accumulated a total right-slip of about 300 km (195 miles). This fault is presently accommodating most of the motion, about 3.5 cm/yr, between the Pacific and North American plates.

The San Gregorio Fault is the principal active fault west of the San Andreas in central California and extends northward from offshore of western Santa Barbara County roughly parallel to the coast to join the San Andreas Fault north of San Francisco. Right-slip on this active fault started before about 10 Ma (probably 11-12 Ma; Clark et al., 1984) and has shifted granitic, Paleogene, and Miocene rocks correlated with similar rocks of the Monterey Peninsula northward about 150 km (90 to 100 miles) to the Point Reyes Peninsula in Marin County (Clark, 1999). Southward, some right-slip from the San Gregorio Fault has been distributed eastward to intra-Salinian faults, including the Monterey Bay/Navy/Tularcitos Fault zone and the Garrapata/Palo Colorado Fault zone. Faulted, folded, and tilted Pleistocene terrace deposits; locally faulted Holocene sediments; and earthquake epicenters that align with these faults indicate ongoing tectonic deformation of these coastal areas.



Another important strike-slip fault is the Rinconada Fault that trends northwestward west of the Salinas Valley. This fault may have experienced as much as 65 kilometers (40 miles) of right slip since early Tertiary time (Dibblee, 1976), and near Lockwood offsets late Pleistocene alluvial fan deposits (Hart, 1985), but Holocene movement has not been demonstrated. Steep reverse faults are common in the Santa Lucia Range and generally place granitic basement rocks in contact with Cretaceous and Tertiary sedimentary rocks. Vertical offset on these faults ranges from 300 meters (1,000 feet) to as much as 3000 meters (10,000 feet). In contrast, the Salinian basement of the Gabilan Range is less slivered by faulting, and the granitic rocks that underlie the Gabilan Mesa have largely been uplifted with little disruption of the overlying Tertiary sedimentary rocks. The exception is along the east side of the range and mesa, where faults included in the long-term San Andreas Fault Zone, such as the Pinnacles, Chalone Creek, Bear Valley, and Bitterwater Valley Faults cut and deform the basement and some, but not all, of the overlying strata.

Thrust faults are less commonly mapped in the Point Sur 30' x 60' quadrangle. The northeast-dipping Sur thrust is an older fault along which Franciscan rocks to the southwest moved under the Salinian block to the northeast during late Cretaceous time. Other thrust faults that resulted from local compression within the Salinian block during Tertiary time include the Los Lobos thrust near San Ardo, and the San Jose thrust in the northern Santa Lucia Range.

## **Folds**

Numerous northwest-trending folds have been mapped mainly in the Tertiary sedimentary rocks of the Santa Lucia Range. Individual folds may be as long as 20 kilometers (12 miles) but generally are less than 3 kilometers (2 miles) long. Many of the folds are very tight, and some are overturned. They commonly parallel the steep reverse faults and were probably formed by the same compressive forces. Likewise the folds that parallel the thrust faults east of Monterey probably formed by the same compressional forces as the nearby thrust faults, and anticlines south of the mapped thrusts are probably underlain by thrust faults that do not reach the surface, "blind thrusts." Northwest-trending folds also underlie the Salinas Valley, where anticlines such as those at the San Ardo and King City oil fields have been the locus of oil field development.

In the Diablo Range block, the Tertiary strata east of the San Andreas Fault are characterized by upright north-northwest trending folds. As in the Salinian block, these folds are generally parallel to reverse and reverse-oblique faults, and probably reflect the same Neogene-Quaternary compression (transpression) associated with uplift of the Diablo Range. The Diablo Range block west of the San Andreas Fault is broken into many fault slivers, so folds are largely not preserved.

In the Nacimiento block, the Tertiary rocks are also largely within fault slivers. The large fault sliver of Tertiary strata southeast of Ventura Rocks is made up of a syncline. In addition, the Sur-Nacimiento Fault that bounds the Nacimiento/Salinian blocks is itself folded, resulting in klippe of Salinian block on Nacimiento block rocks east of Dolan Rock, Square Black Rock, and Gamboa Point.

## **Regional Stratigraphy**

The rocks of the Point Sur 30' x 60' quadrangle have formed under a diverse variety of hot, molten igneous; high temperature and(or) pressure metamorphic; and surficial sedimentary conditions. The older igneous and metamorphic rocks form the crystalline basement upon which were deposited sedimentary rocks ranging in age from Cretaceous to Holocene. The composite thickness of all Cretaceous through Holocene sedimentary rocks is estimated to be more than 10,000 meters (30,000 feet) in the Salinian Block. Because of periodic uplift and erosion, nowhere in the map area is a complete sequence of these sedimentary rocks preserved. In general, the older (pre-Miocene) sedimentary rocks are found northeast of the San Andreas Fault zone, southwest of the Sur/Nacimiento Fault zone, and in faulted areas of the Santa Lucia Range. The thickest section of sedimentary rocks underlies the Salinas Valley and the area to the west, south of Greenfield, where more than 3500 meters (12,000 feet) of Miocene and younger rocks are present. The major rock units and their distributions are summarized below, from oldest to youngest.

## **Salinian Complex**

### **Metamorphic Rocks of the Salinian Complex**

The oldest rocks exposed in the Point Sur 30' x 60' quadrangle are the metamorphic rocks of the Salinian complex. These rocks are described as chiefly of Quartzofeldspathic gneisses and granofelses and biotite-feldspar quartzites, with lesser amounts of schist and marble (Wiebe, 1966). These rocks are believed to have been laid down in a shallow sea as thin beds of siltstone, sandstone, shale, limestone, and dolostone before being deeply buried, then intruded in late Cretaceous time by granitic material and metamorphosed at high temperatures. Although their protolith age is uncertain, studies of detrital zircons

suggest them to be Paleozoic in age (Barbeau et al., 2005). These metasedimentary rocks are widespread in the Santa Lucia Range, where they underlie an area of about 900 square kilometers (350 square miles). Small bodies of these rocks are widely distributed in the Gabilan Range. Bodies of marble are scattered throughout the ranges and form prominent topographic features at Pico Blanco near Big Sur and at Fremont Peak in the northern Gabilan Range. The metamorphic rocks of the Salinian Block were described as the Sur series by Trask (1926). This term was never formalized with a type section, or any stratigraphic order. As a result the term “Sur series” means no more than “metamorphic rocks of the Salinian complex” and is not used on this map.

## **Salinian Complex Granitic Rocks**

Intrusive into the metamorphic rocks of the Salinian complex are large granitic rock bodies that range in composition from granite to quartz diorite. Radiometric dating indicates that these granitic rocks are of late Cretaceous age (see section on Regional Geology).

The granitic rocks underlie most of the map area, and are exposed in most of the Gabilan Range and northern Santa Lucia Range, and extend offshore to the northwest of Monterey, where it is truncated by the San Gregorio Fault. The distinctive Monterey mass of Ross (1976), which includes large crystals of feldspar, has been mapped offshore to the San Gregorio Fault zone. This unit has been correlated with the porphyry granitic rock at Point Reyes, suggesting that the western part of the Monterey mass has been displaced northward to the Point Reyes Peninsula by 150 km offset along the San Gregorio Fault.

## **Franciscan Complex**

The Franciscan Complex includes the oldest rocks exposed in the Nacimiento block and the Diablo Range block. Rocks of this complex in and around the map area are made up of relatively coherent bodies in multi-kilometer scale fault bounded lenses surrounded by *mélange*, rocks that were pervasively sheared and partially metamorphosed during subduction beneath the western edge of North America. *Mélange* is characterized by small (relative to the fault bounded lenses described above, though some still as large as 100s of meters across) blocks of coherent rock in a matrix of totally disrupted and sheared rock. *Mélange* matrix is typically composed of shale and sandstone, but also may include altered tuff. Serpentine-matrix *mélange* is also found in the Coast Ranges outside the map area, though that is more typically related to the Great Valley complex (see below). Typical rocks found in both the large fault bounded lenses and the *mélange* blocks include dark-gray sandstone (graywacke), black shale, thinly bedded red chert and shale, and altered mafic volcanic rocks (greenstone). Blueschist, which presumably formed under high-pressure and low-temperature conditions during subduction, serpentinite, and other metamorphic rocks are less common and only found in the map area as *mélange* blocks. Fossils are rare in the Franciscan Complex, which ranges from Jurassic to Late Cretaceous age.

## **Great Valley Complex**

The lowest unit of the Great Valley complex is the Middle Jurassic (~165 Ma) Coast Range ophiolite. This unit includes all the standard ophiolite components outside the map area (in most places tectonically slivered and in some reduced to serpentinite-matrix *mélange*), but within the map area the unit is only represented by scattered lenses of serpentinite. Because the Franciscan Complex was subducted under the Coast Range ophiolite, some, but not all, Franciscan Complex serpentinites are thought to have been derived from the base of the Coast Range ophiolite and tectonically mixed into

Franciscan Complex *mélange* (distinguishing between serpentinites of different origin requires detailed mineralogic studies that have not been done for any of the serpentinites in the map area).

Overlying the ophiolite are the marine sandstone and shale of the Great Valley sequence, deposited during late Jurassic and Cretaceous time. Although many thousands of feet thick to the east of the map area, the confidently identified Great Valley sequence in the map area is limited to fault lenses within the long-term San Andreas Fault Zone and a small area in the northeast corner of the map.

Southwest of the San Gregorio Fault near the mouth of the Little Sur River, as much as 1200 meters (4,000 feet) of Upper Cretaceous interbedded marine sandstone and shale are in fault contact with Franciscan rocks. These lightly sheared but unmetamorphosed rocks have been included by earlier workers in both the Great Valley and Franciscan complexes.

## **Schist of Sierra de Salinas**

This schist is more homogeneous and differs from the rest of the metamorphic rocks in the main part of the Salinian block. Composition of the schist suggests that it was formed from a thick section of clay-rich sandstone (graywacke). About 350 square kilometers (100 square miles) of the eastern Santa Lucia Range are underlain by this schist, where it is estimated to be as thick as 1500 meters (5,000 feet). Well cores suggest that similar schist occurs beneath the Salinas Valley as far south as San Ardo. Studies of detrital zircons in the schist have shown the protolith to be late Cretaceous (<81 Ma; Barth et al., 2003), younger than the age of the adjacent granitic rocks (Ducea et al., 2009). Therefore, the schist cannot be part of the metamorphic complex described above. Instead, the schist protolith was overthrust by the granitic/metamorphic rocks of the Salinian complex in Late Cretaceous time. Restoration of San Andreas Fault offset places the schist adjacent to similar schist of late Cretaceous and Paleocene metamorphic age in southern California (Rand-Pelona-Orocopia schist), with which the schist of Sierra de Salinas has been correlated. (Ross, 1976; Jacobson et al., 2000).

## **Sedimentary Rocks of the Salinian Block**

Post-basement sedimentary rocks record a roughly west to east marine transgression across the map area that occurred between latest Cretaceous and late Miocene time. Formations laid down during the latest Cretaceous, Paleocene, Eocene, and Oligocene Epochs are exposed in only a few areas of the Santa Lucia Range. In the Santa Lucia Range, Upper Cretaceous strata are discontinuously exposed in a broad band that stretches southward from west of Junipero Serra Peak to Lake Nacimiento. These beds rest on Salinian basement rocks and are composed predominantly of marine sandstone and conglomerate with lesser amounts of mudstone that represent slope and submarine fan deposits. The Upper Cretaceous section in the Hunter Liggett Military Reservation is as much as 4000 meters (13,000 feet) thick (Seiders, 1989a). Similar rocks crop out overlying the granitic/metamorphic rocks in the Big Sur area east of the San Gregorio Fault, and in fault bounded lenses west of Ventana Double Cone and southeast of Rocky Point. Southwest of Junipero Serra Peak, as much as 1500 meters (5,000 feet) of mudstone and sandstone with minor conglomerate were deposited during Paleocene time in the same deep marine basin as the underlying Upper Cretaceous beds. This unit extends to the north as topographically high eroded remnants, and occurs to the east of Junipero Serra Peak as a fault-bounded lens.

An Eocene to lower Miocene section that is more than 1500 meters (5,000 feet) thick crops out over a distance of about 65 kilometers (40 miles) in a faulted area of the northern Santa Lucia Range. The shallow-marine Junipero Sandstone forms the base of the Eocene sequence and rests on the crystalline

basement complex and locally to the southwest on older Paleocene and Upper Cretaceous strata. The overlying Eocene section consists of the deep-marine Lucia Mudstone, the deep-sea fan deposits of The Rocks Sandstone, and marine mudstone and sandstone beds with minor conglomerate interbeds of the Church Creek Formation.

The Church Creek Formation is overlain by and locally intertongues with shallow-marine to nonmarine sandstone and conglomerate beds of the Berry Conglomerate of Oligocene age. The shallow-marine Vaqueros Sandstone, which contains abundant mollusks of Oligocene (locally) and early Miocene age, forms the top of this section.

Volcanic rocks of Oligocene age are discontinuously exposed in Carmel Valley and the northernmost Santa Lucia Range. Rhyolitic to andesitic volcanic rocks of late Oligocene and early Miocene age form the picturesque exposures of the Pinnacles National Park in the southern Gabilan Range.

Miocene sedimentary rocks are widespread. North of Arroyo Seco the section consists of marine and nonmarine sandstone beds overlain by the Monterey Formation. The nonmarine red beds and basal marine arkosic sandstones locally rest on the crystalline rocks of the Salinian block and Oligocene volcanic rocks in the northern Santa Lucia Range. These basal sandstones are locally thin or missing but south of Carmel Valley are as thick as 180 meters (600 feet). South of Arroyo Seco, the basal part of the section consists of Monterey Formation as old as early Miocene overlying Vaqueros Sandstone in the Salinas basin west of the Salinas Valley, or Berry Conglomerate in the subsurface southwest of Greenfield (Monroe Swell Oil Field). In the subsurface southwest of King City these strata are more than 300 meters (1,000 feet) thick.

The deep-marine Monterey Formation is named for typical exposures near the city of Monterey. This formation crops out almost continuously west of the Salinas Valley from the northern Santa Lucia Range southward to San Luis Obispo County. In this area, the Monterey usually consists of three distinct units, locally mapped as members. The lowest member is siltstone to soft claystone and ranges from 100 to 300 meters (1,000 feet) thick. The middle member is the typical hard, siliceous mudstone and porcelainite that characterize this formation and reaches a maximum thickness of 3500 meters (12,000 feet) in the Salinas basin (Kilkenny, 1948). The upper member consists of as much as 150 meters (500 feet) of white soft, impure diatomite. East of Salinas Valley, the Monterey is limited to late Miocene, underlying and interfingering with the Santa Margarita Sandstone (see below). In the Pinnacles area, the middle and late Miocene is recorded by the Bickmore Canyon Arkose, not the Monterey. Bickmore Canyon Arkose formed as poorly sorted shallow marine deposits near in a pull-apart basin, and later adjacent to an east-facing escarpment, related to a releasing right step in the San Andreas Fault Zone. This depocenter was separated from the coeval depocenters in the rest of the map area by a basement ridge extending from the south end of the Gabilan Range.

Overlying the upper diatomite of the Monterey Formation are white, arkosic sandstone beds of the Santa Margarita Sandstone that locally contain marine mollusks and echinoids of late Miocene age. East of Monterey, this sandstone formation is about 150 meters (500 feet) thick. Farther to the east and west of the Salinas River, where the Monterey Formation grades laterally into sandstone, the middle and upper Miocene section consists entirely of as much as 550 meters (1,800 feet) of arkosic sandstone.

The Pancho Rico Formation crops out extensively east of the Salinas River and caps the Gabilan Mesa east of King City and consists of as much as 300 meters (1,000 feet) of sandstone, siltstone, and diatomite. West of the Salinas Valley the outcrop is more limited, and ranges in thickness from 60 meters (200 feet) near the San Antonio River to as much 380 meters (1,250 feet) near the mouth Arroyo Seco.

Locally this formation contains abundant mollusks, echinoids, and barnacles of shallow-marine origin and diagnostic of latest Miocene age and includes beds of early Pliocene age.

### **Tertiary Rocks of the Diablo Range Block**

Only a small area of the Diablo Range block is included on the Point Sur 30x60' quadrangle. This area includes parts of two sub-blocks separated by the presently active San Andreas Fault. To the west lies the Little Rabbit Valley sub-block, bounded on the west by the Bear Valley Fault. Graymer (p.c. 2016) reports that this sub-block is comprised of Franciscan and Great Valley complex rocks, interleaved with fault slivers of a dismembered Tertiary section. The oldest unit in the Tertiary section is the Oligocene? and early Miocene Temblor Sandstone, followed by middle to lower Miocene Monterey Shale, and upper to middle? Miocene Santa Margarita Sandstone. This "section" is unlike the section to the east, and best matches the stratigraphy of the Temblor Range to the southeast, suggesting that the Little Rabbit Valley sub-block is a sliver of Temblor Range rocks transported to the map area by offset along the San Andreas Fault. This idea is supported by the correlation of biomarkers in the oil from the Bitterwater Oil Field (along strike with the Little Rabbit Valley block along the San Andreas Fault just east of the map area) with those from oil in the Lost Hills and Belridge fields adjacent to the northern Temblor Range (Peters et al., 2013).

East of the San Andreas Fault lies the San Benito sub-block, composed of Cretaceous Great Valley Sequence strata overlain by a Tertiary section that includes a tiny sliver along the northern map edge of Santa Margarita Sandstone and, more widely, fossiliferous, shallow-marine sandstone beds mapped by Dibblee (1971) as Echegoin Formation. The Echegoin is lithologically similar to the older Jacalitos Formation. The faulted sections and lack of diagnostic fossils in this area prevent positive identification. This unit is therefore designated the Echegoin and Jacalitos, undivided. Also present, as a sliver along the Pine Mountain Fault, is a basalt of unknown age. The relatively unaltered nature of the basalt suggests that it is Tertiary, probably a scrap of Miocene volcanic rock from the northward-younging volcanic fields associated with the northward migration of the Mendocino Triple Junction.

### **Tertiary rocks of the Nacimiento Block**

Tertiary units do not crop out over extensive areas of the Nacimiento Block. They are found mostly in the Sur syncline near the mouth of the Little Sur River. Despite the limited outcrop area, these Tertiary sedimentary rocks have been shown to be distinct from the units overlying the Salinian block basement. The reason for the differences is that these units represent a different sedimentary basin that has now been displaced by the San Gregorio-Hosgri fault. Hall (1991) correlates the sedimentary units deposited on Franciscan complex bedrock west of the Sur fault with units in the Cambria-Morro Bay area 95 to 130 km (60 – 80 mi) to the south. These units include the Vaqueros Formation, which is also found on the Salinian block, but on the Nacimiento Block is overlain by Rincon Shale and Pismo Formation rather than the Monterey and Pancho Rico Formations.

The Vaqueros Formation and Rincon Shale are known from only a few small outcrops near the mouth of the Little Sur River. There, the Vaqueros has a maximum thickness of 35 meters (115 ft) and consists of sandstone and conglomerate, with sedimentary breccia near the base. The Rincon Shale is composed of deeply weathered brown, silty claystone with sandy siltstone. It has a maximum thickness of 125 meters (410 ft). Rincon Shale conformably overlies the Vaqueros Sandstone and unconformably overlies the Franciscan Complex.

The Pismo Formation crops out along the cliffs north of the Little Sur River to Hurricane Point. Hall (1991) describes the Edna and Miguelito Members of the Pismo Formation. The Edna Member consists of fine- to medium-grained, poorly bedded, and cross-bedded arkosic sandstone. The Miguelito Member consists of well-bedded, siltstone and fine-grained micaceous quartzofeldspathic sandstone. Hall interprets the Edna Member as representing deltaic deposits and the Miguelito Member as deposits of turbidite currents on a delta slope. Thickness of the Pismo Formation in this area is estimated to be up to 430 meters (1,400 feet). Rare conglomerate beds within the Edna Member include clasts of rhyodacite or felsitic rocks derived from the Morro Rock-Island Hill Complex or Cambria Felsite, supporting the interpretation of large displacement on the San Gregorio-Hosgri Fault.

## **Quaternary Deposits**

Quaternary deposits are widespread throughout the Point Sur 30x60' quadrangle and were formed in a variety of environments. The oldest units (in part Pliocene) are the Paso Robles Formation and equivalent continental deposits, found mainly in the foothills of the southern Salinas Valley, Gabilan Mesa, and Jolon Valley. The Paso Robles Formation is as much as 900 meters (3,000 feet) thick and consists of conglomerate, sandstone, and mudstone composed of sediments shed from the uplifting Santa Lucia and La Panza Ranges (Galehouse, 1967), as well as locally from the Gabilan and Diablo Ranges.

A flight of marine wave-cut terraces formed along the coast as a result of sea level changes and uplift of the Santa Lucia Range during the Pleistocene. Dupré (1990) mapped six levels of terraces on the Monterey Peninsula. In Carmel Valley, some of the marine terraces grade into stream terraces (Williams, 1970). The terraces extend along the entire coast, but are difficult to correlate south from Monterey into the less-studied area of the Point Sur 30x60' quadrangle because they cross large faults with uncertain amounts of displacement.

Fluctuating sea levels during Pleistocene time caused the Salinas River to deposit a complex series of estuarine and alluvial deposits during sea level high stands, and erode through those deposits during low-stands to form a series of stream terraces. The terraces in the valley and alluvial fans along the base of the Santa Lucia and Gabilan ranges characterize the landscape of the Salinas Valley, as well as forming the aquifer that supplies much of the area's water (Tinsley, 1975). Mapping of the alluvial deposits by Tinsley (1975), Dohrenwend (1975), and Taylor and Sweetkind (2014) allow for correlation of extensive alluvial deposits in the valley. In addition to the multiple generations of alluvial fans and floodplain deposits in the valley, stream terraces in the Santa Lucia and Gabilan ranges record uplift of those ranges and erosion of stream canyons through them. Modern-day rivers and streams erode and transport material from the hills to lower elevations. Some of these sediments are deposited in the active flood plains; the remainder eventually reaches the Pacific Ocean and is deposited offshore.

## Description of Map Units

The arrangement of map unit descriptions on the map sheet roughly illustrates the correlation of map units among different tectonic blocks and depositional basins. The map area straddles three major geologic provinces, the Nacimiento, Salinian, and Diablo Range blocks as described above.

Similarities and differences among rock units are incompletely reflected in the nomenclature and labeling of the rock units, which evolved from many geologic investigations over the past century. The majority of the units on this map have been adopted from the source maps used in this compilation. Named Formations of sedimentary strata are made up of multiple episodes of individual depositional events and each event need not be distributed over exactly the same area. This can lead to significant differences in the age range of a rock stratigraphic unit from one area to another.

Map labels are abbreviations that indicate age and origin of surficial deposits, or age and formally recognized names of formations and members. Where stratigraphic assignment is tentative, a query (?) is added to the label in the database. Where informal subunits are represented by subscripted numbers, numbers increase with decreasing age (i.e., of subunits 1-4, 1 is the oldest and 4 is the youngest). Quaternary deposits are found in all provinces and subareas; however they are relatively local in extent, and deposits are commonly associated with distinctive geomorphic features such as fans, flood plains and terraces.

- af Artificial fill (late Holocene)**—Deposits of sand, silt and gravel resulting from human construction, mining or quarrying activities; includes compacted engineered and non-compacted non-engineered fill. Only large deposits are shown. Fills emplaced after source maps were completed are generally not shown.
- Qsc Modern stream channel deposits (Holocene)**—Unconsolidated, moderately well-sorted gravel, sand and silt in active or recently active streambeds; chiefly stream deposited, but includes some debris-flow deposits; episodes of bank-full stream flow are frequent enough to inhibit growth of vegetation. Mapped along the Salinas River and major tributaries, including most recent channel and less recently inundated bars and terraces mapped by Taylor and Sweetkind, 2014), Durham 1963, 1970; Dohrenwend (1975); Tinsley (1975); Dibblee (1971).
- Qya Young alluvium (Holocene)**—Unconsolidated gravel, sand and silt in active or recently active floodplains, locally including related alluvial fans and streambeds where those are not mapped separately; chiefly stream deposited, but includes some debris-flow deposits. Deposits are near or in the locus of recent sedimentation, though locally the most recently active surfaces may be mapped separately as Qsc. Surfaces generally not uplifted or dissected; and show poorly-developed pedogenic soils. Subunits are distinguished by relative ages based on geomorphic relationships, relative degree of surface dissection and soil formation. Includes undifferentiated alluvium (Qal) and flood plain deposits (Qfp) of Dibblee (1972); younger flood plain deposits (Qyf) of Tinsley (1975) and Dupre (1990) and basin deposits (Qb) of Tinsley (1975) and McKittrick (1987).
- Qya3 Young alluvium (Holocene)**—Alluvium in modern, lower floodplains, between level of more extensive Qya2 surface and current stream channel. Consists of pebbly, moderately well-sorted, medium- to fine-grained gravel, sand and slit, capped by minimally developed soils.

- Qya2 Young alluvium (Holocene)**—Alluvium in modern, lower floodplains. Consists of pebbly, moderately well-sorted, medium- to fine-grained gravel, sand and silt, capped by minimally developed soils. Sub-unit Qya2m includes Metz terrace (Qmz) of Tinsley (1975) in the Salinas Valley.
- Qya1 Young alluvium (Holocene)**—Alluvium in modern, higher floodplains. Consists of pebbly, moderately well-sorted, medium- to fine-grained sand and silt deposited from standing or very slowly moving water during extreme flood events. Floods of 1968-1969 inundated parts of this surface in the Salinas Valley. Deposits are capped by undeveloped to minimally developed soils. Sub-unit Qya1s includes Salinas terrace (Qsl) of Tinsley (1975) and Salinas-Docas surface (Qts) of Dohrenwend (1975) in the Salinas Valley.
- Qyf Young alluvial fan deposits (Holocene)**—Unconsolidated gravel, sand and silt, bouldery along mountain fronts; deposited chiefly from flooding streams and debris flows. Deposits are clearly related to depositional processes that are still on-going. Subunits are distinguished by relative ages based on geomorphic relationships, relative degree of surface dissection and soil formation. Includes Holocene alluvial fan deposits (Qhf) of Tinsley (1975) and Klaus (1999).
- Qbs Beach Sand (Holocene)**—Unconsolidated, well-sorted medium to coarse sand.
- Qdf Recent Debris Fan (Holocene)**—Unconsolidated gravel, sand and silt, bouldery along mountain fronts; deposited mainly by debris flows rather than fluvial processes. Deposits are clearly related to the most recent depositional processes. Poorly-bedded brown silty sand with angular rock fragments. Geomorphically distinct fan shapes are still observable. Includes vegetated talus- like slopes.
- Qydf Younger Debris Fan (Holocene to Latest Pleistocene)**—Unconsolidated gravel, sand and silt, bouldery along mountain fronts; deposited mainly by debris flows rather than fluvial processes. Deposits are clearly related to depositional processes that are still on-going. Distinguished from older and most recent debris fan deposits by relative ages based on geomorphic relationships, relative degree of surface dissection and soil formation. Deposits consist of poorly bedded reddish brown silty sand with angular rock fragments. Locally contains areas or layers of well-bedded gravelly silty sand that represent stream- deposited alluvium.
- Qe Eolian deposits (Holocene)**—Unconsolidated, loose to medium dense, yellow brown, medium- to fine-grained sand. Subaerially deposited adjacent to coast and in Salinas Valley. Includes dune deposits (Qd) from Hall.
- Qls Landslide Deposits (Holocene to Pleistocene?)**—Only selected landslide deposits are shown on this map as described below. Composed of rock detritus from bedrock and/or surficial materials, broken in varying degrees from relatively coherent large blocks to disaggregated small fragments, deposited by landslide processes. Most deposits are Holocene, some dissected landslides may be as old as late Pleistocene. For this map, only landslides larger than 50,000 square meters are shown to preserve the clarity of the underlying bedrock geology. Selected historically active landslides between 10,000 and 50,000 square meters are shown, but no landslides smaller than 10,000 square meters are shown on this map.

Exceptions to these rules include small or questionable landslides surrounded by larger probable or definite landslides.

## Pleistocene

- Qoa Older alluvium (Holocene? to Pleistocene)**—Unconsolidated to moderately indurated gravel, sand and silt deposited on flood plains, locally including related alluvial fans where those are not mapped separately. Deposits have been uplifted or otherwise removed from the locus of recent sedimentation. Surfaces may be dissected in varying degrees; and can show moderately to well-developed pedogenic soils. Subunits can be distinguished by relative ages based on geomorphic relationships, relative degree of surface dissection and soil formation. Dupre (1990), mapped contacts between subunits in the Carmel Valley but did not apply different names, so those subunits are all designated Qoa. Includes older flood plain deposits (Qof) of Tinsley (1975). Includes terrace deposits, (Qt) of Tinsley (1975) and Dupre (1990). Mapped by Seiders (1983); Dibblee (1971, 1972), Dupre (1990), and Dickinson, (1965).
- Qodf Older Debris Fan deposits (Holocene? to Pleistocene)**—Slightly to moderately consolidated silt, sand and gravel deposits on alluvial fans dominated by debris flow, rather than fluvial, processes. Poorly-bedded, reddish-brown silty sand with angular rock fragments. Mapped along coast where debris fans were deposited onto marine wave cut platforms or marine deposits and locally inland. Fan shape often lost to erosion. Typically consists of angular rock fragments in sandy clay matrix deposited from numerous debris flow and debris slide events. Clast support observed, often at base of fan (i.e., stone line) in paleochannel or near source area of debris. Some outcrops have been cemented and oxidized to deep rusty color, with zones of apparent leaching adjacent to fractures within the unit. Unit can be 30 m (100 ft) thick to thin layer over bedrock.
- Qoe Older Dune Sand (Holocene? to Pleistocene)**—Unconsolidated, commonly with lightly cemented crust, medium dense to very dense, yellow to reddish brown, medium- to fine-grained sand subaerially deposited in Salinas Valley and adjacent to coast.
- Qof Older alluvial fan deposits (Holocene? to Pleistocene)**—Slightly to moderately consolidated silt, sand and gravel deposits on alluvial fans. Deposits have been uplifted or otherwise removed from the locus of recent sedimentation. Morphology of original alluvial fan surface usually well preserved, though dissected in varying degrees; surfaces can show moderately to well-developed pedogenic soils. Subunits are distinguished by relative ages based on geomorphic relationships, relative degree of surface dissection and soil formation. Includes Late Pleistocene alluvial fans of Klaus (Qfpl) (1999) and undifferentiated Pleistocene alluvial fans (Qfu) of Durham (1970) and Dibblee (1971, 1972). Subdivided in Salinas Valley and Arroyo Seco as described below.
- Qof5 Older alluvial fan deposits (Pleistocene)**—Weakly consolidated, slightly to moderately weathered, irregularly interbedded, moderately to poorly-sorted gravel, sand, and silt. Deposits form terraces, primarily on the east side of the Salinas Valley and narrow terraces along Arroyo Seco. Taylor and Sweetkind (2014) describe the soils as including a Bt horizon with a brownish (10YR) hue and about 45% clay. Taylor and Sweetkind (2014) interpret the

deposit to be approximately 20,000 to 30,000 years old. Includes most areas mapped as intermediate age alluvial fan deposits (Qfai4) of Taylor and Sweetkind.

- Qof4 Older alluvial fan deposits (Pleistocene)**—Weakly consolidated, slightly to moderately weathered, irregularly interbedded, moderately to poorly-sorted gravel, sand, and silt. Deposits form prominent alluvial fans on both sides of Salinas Valley and narrow terraces along Arroyo Seco. Alluvial deposits are capped by medially developed soils. Taylor and Sweetkind (2014) describe the soils as including a Bt horizon that ranges from brown (10YR) to reddish-brown (7.5YR) in hue. Sample from alluvial deposit near mouth of Arroyo Seco dated at  $35,350 \pm 3,680$  years old (Taylor and Sweetkind, 2014). Includes most areas originally mapped as Chualar alluvial fan surfaces (Qch) by Tinsley (1975) and Chualar-Rincon terraces (Qtr) of Dohrenwend (1975) most of these were mapped as intermediate age alluvial fan deposits (Qfai3) by Taylor and Sweetkind.
- Qof3 Older alluvial fan deposits (late Pleistocene)**—Weakly consolidated, slightly to moderately weathered, irregularly interbedded, moderately to poorly-sorted gravel, sand, and silt. Deposits form prominent alluvial fan on the west side of the Salinas Valley south of the Arroyo Seco and narrow terraces along Arroyo Seco. Taylor and Sweetkind (2014) describe the soils as including a Bt horizon with a brownish (10YR) hue and about 35% clay. Samples from alluvial deposits in Arroyo Seco have been dated at  $50,640 \pm 2,980$  and  $45,960 \pm 1,840$  years old (Taylor and Sweetkind, 2014). Includes some areas originally mapped as Chualar alluvial fan surfaces (Qch) by Tinsley (1975) and intermediate age alluvial fan deposits (Qfai2y) of Taylor and Sweetkind.
- Qof2 Older alluvial fan deposits (late Pleistocene)**—Weakly to semi-consolidated, moderately weathered, irregularly bedded moderately to poorly-sorted gravel, sand, and silt. Deposits form narrow terraces along Arroyo Seco. Distinguished geomorphically from Qof3, but have essentially identical soils. Taylor and Sweetkind (2014) estimate the deposits to be about 65,000 years old. Includes intermediate age alluvial fan deposits (Qfai2o) of Taylor and Sweetkind.
- Qof1 Older alluvial fan deposits (Pleistocene)**—Weakly to semi-consolidated, moderately weathered, irregularly bedded, moderately to poorly-sorted gravel, sand, and silt. Gravel content increases near fan heads, capped by maximally developed soils. Taylor and Sweetkind (2014) describe the soils on this unit as including a Bt horizon that ranges from brown (10YR) to darker reddish-brown (5YR) in hue. Unit includes alluvial fan deposits of Placentia (Qp) of Tinsley (1975), Placentia-Chamise terraces (Qtp) of Dohrenwend (1975) and intermediate age alluvial fan deposits (Qfai1) of Taylor and Sweetkind.
- Qom Marine terrace deposits (late Pleistocene)**—Clast-supported deposits of relatively uniform grain size overlying wave cut benches. Some deposits contain subrounded to rounded clasts ranging in size from pebbles to boulders (0.5 – 1 m (2-3 ft) in diameter. May contain dune sand, and grade into dune deposits.
- Qom1 Marine terrace deposits (late Pleistocene)**—Older, topographically higher of two ages of marine (beach and nearshore) deposits on wave-cut terrace landform can be discerned locally.

**Qvoa Very old alluvium (Pleistocene)**—Remnants of alluvial surfaces that do not have distinct fan morphology. Mapped by (Hall, 1991), on ridge tops west of the Big Sur River and Klaus (1999) near the southern edge of the quadrangle in the Santa Lucia range.

**Qvoa1–Qvoa8 Very old alluvium (middle to early Pleistocene)**—Eroded remnants of fluvial or alluvial fan deposits on terraces above the Arroyo Seco drainage mapped by Taylor and Sweetkind (2014). Units are designated from oldest (Qvoa1) to youngest (Qvoa8) based on interpretations of elevation and projected original stream profiles by Taylor and Sweetkind (2014). Deposits consist of poorly sorted sand and gravel, locally including rounded boulders.

**Qvof Very old alluvial fan deposits (late middle Pleistocene)**—Eroded remnants of alluvial fans along the sides of the Salinas Valley north of the town of Greenfield. Deposits consist of moderately- consolidated, moderately to deeply- weathered, irregularly bedded, moderately to poorly-sorted gravel, sand, and silt. Gravel content increases near fan heads. Taylor and Sweetkind (2014) describe the soils on this unit as including a Bt horizon that ranges from reddish-brown (7.5YR) to darker reddish- brown (5YR) in hue and includes a silica-cemented duripan in the C horizon. Described as alluvial fan deposits of Gloria (Qgl) by Tinsley (1975) designated Qao by Taylor and Sweetkind (2014).

#### Plio-Pleistocene to Late Cretaceous strata

**QRp Paso Robles Formation, undifferentiated (Pleistocene and Pliocene)**—Pebble conglomerate, sandstone and mudstone. Sandstone is described as conglomeratic, arkosic, massive to poorly-bedded, poorly-sorted and friable. Sandstone is locally calcite cemented. Lack of marine fossils and resemblance to older alluvial deposits indicates non-marine fluvial and alluvial fan deposition. Clasts generally locally derived, predominantly Monterey Formation in area mapped by Durham (1963). Includes mudstone of the Paso Robles Formation described by Durham (1964), as pale orange, massive to thick-bedded, containing scattered pebbles. Includes un-named nonmarine sandstone and siltstone of Dibblee (1971) and McKittrick(1987) in upper Tularcitos Canyon; Also mapped by Dohrenwend (1975), Matthews, (1973).

**RMej Etchegoin Formation and Jacalitos Formation, undivided (Pliocene to late Miocene)**—Light gray, blue gray, and white arkose; weathers brown. Includes quartz-lithic sandstone, pebbly sandstone, conglomerate, dark gray and brown mudstone, and dark gray shale Dibblee, (1971) Graymer (p.c. 2015).

**RMips Pancho Rico Formation sandstone (early Pliocene to late Miocene)**—Light brown, locally white or yellowish gray, fine or very fine-grained, massive, arkosic, noncalcareous, sandstone. Includes some beds of medium- to coarse-grained sandstone, as much as 3 m (10 ft) thick. These are generally massive, yellowish gray or yellowish brown and friable to well-indurated. Includes sandstone mapped by Dibblee (1971) as overlying un-named marine sandstone (Tucs). Overlies Monterey Fm and underlies Paso Robles and is conformable and probably gradational with both. Total thickness of the Pancho Rico Formation ranges from less than 60 to as much as 300 m (200 - 1000 ft) (Durham and Addicott, 1965), Durham (1963), Durham and Addicott (1965), Dibblee (1971), Graymer (p.c. 2015).

- R<sub>M</sub>po Pancho Rico Formation mudstone (early Pliocene to late Miocene)**—Light brown marine siltstone, claystone and diatomaceous shale, massive, noncalcareous, with scattered very fine sand grains and mica flakes in a matrix of silt and clay. Mudstone contains abundant diatom and locally common fish scale and pelecypod fossils. Basal part in the southeastern Gabilan Range includes lenses of white-weathering diatomite that have yielded 5.9-6.7(6.3?) Ma diatoms. Durham and Addicott (1965), Dibblee (1971), Graymer (p.c. 2015).
- R<sub>M</sub>pm Pismo Formation, Miguelito member (late Miocene)**—Well-bedded, locally thin-bedded siltstone and fine- to rarely coarse-grained micaceous sandstone. Dark gray to dark brown on unweathered surfaces, light gray to tan or orangish-brown when weathered. Thickness estimated to be about 550 m. (Hall, 1991)
- R<sub>M</sub>ppe Pismo Formation, Edna member (late Miocene)**—Fine to medium-grained, thinly to thickly bedded sandstone, locally poorly cemented to friable. Conglomerate beds include granitic and volcanic rocks, the volcanic rocks correlative with Cambria felsite or Morro Rock-Islay Hill complex. Thickness estimated to be from 170 to 400 m.; found north of the Little Sur River to Hurricane Point (Hall, 1991).
- M<sub>1</sub>sm Santa Margarita sandstone (late middle? to late Miocene)**—Pale brown to white, weakly-consolidated, coarse arkosic sandstone. Includes interbedded mudstone, siltstone and diatomite, mostly in the lower part of the unit. Sandstones contain pebble and small cobble lenses. Base of the unit faulted everywhere in the map area. Presumably originally deposited on Monterey Shale or Mesozoic basement locally. Limited to the Diablo Range block to the east Dibblee (1971), Graymer (mapping in progress).
- M<sub>1</sub>bc Bickmore Canyon arkose (middle and late Miocene)**—Coarse arkosic gravel and conglomerate including angular blocks of granitic and volcanic rocks of the Pinnacles volcanic center. Crudely bedded to massive, with local cross-bedding, pale brown to greenish gray, includes lenses of white diatomaceous shale. Lower part is marine, whereas upper part has been interpreted to be primarily non-marine to estuarine deposition. The lower part of this unit in the map area has yielded 8.0-8.6 Ma diatoms. Matthews, (1973), Dibblee (1971), Graymer (mapping in progress).
- M<sub>1</sub>m Monterey Formation, undifferentiated (early (?) to late Miocene)**—White to light gray-brown siliceous shale, thin-bedded, porcelaneous mudstone and shale, porcelanite, diatomite, and chert in nomenclature of Bramlette (1946), (Graham, 1976). Small areas of Monterey Fm in San Andreas fault zone not correlated with members defined in Salinian Block.
- M<sub>1</sub>m<sub>h</sub> Monterey Formation, Hames Member (middle (?) to late Miocene)**—White to light gray-brown siliceous shale, thin-bedded, porcelaneous mudstone and shale, porcelanite, diatomite, and chert in nomenclature of Bramlette (1946), (Graham, 1976). Lesser amounts of sandstone, volcanic ash, phosphorite, and carbonate concretions. Generally gradational contact with underlying Sandholdt member.
- M<sub>1</sub>msl Monterey Formation, Sandholdt Member, semi-siliceous mudstone sub-member (early to middle Miocene)**—Semi-siliceous mudstone composed of terrigenous silt and abundant foraminifera tests, typically platy and laminated. Includes minor sandstone beds, phosphorite and tuff beds. Distinguished from calcareous mudstone by Dibblee (1971, 1972).

- M<sub>1</sub>msc Monterey Formation, Sandholdt Member, calcareous mudstone sub-member (early to middle Miocene)**—Calcareous mudstone, composed of terrigenous silt and abundant foraminifera tests, typically platy and laminated. Includes minor sandstone beds, phosphorite and tuff beds (Graham, 1976). Distinguished from semi-siliceous mudstone by Dibblee (1972).
- M<sub>1</sub>ts Unnamed marine sandstone (early to middle Miocene)**—Buff to white, fine-grained, well-sorted arkosic sandstone. Includes small pelecypods and other fossils in discontinuous layers up to 3 m (ten ft) thick. Includes “Laurelles” sandstone of Neel (1963). Laurelles sandstone first described by Cassell (1949) as basal sandstone of Monterey Formation. Also includes “Tierra Redonda Formation” of Durham (1970) in central Santa Lucia range. As described by Neel (1963), maximum thickness is about 200 m (650 ft). Unconformably overlies crystalline basement rocks. Unconformity has significant local relief, contact with overlying Monterey Formation is gradational within a thickness of about 6 m (20 ft). Mapped by McKittrick (1987) and Rosenberg (unpub) in northern Santa Lucia range.
- M<sub>1</sub>rb Unnamed red beds (early to middle Miocene)**—Red, green and buff, coarse-grained, poorly-sorted, angular, continental arkose. Includes well-rounded clasts of schist and quartz diorite to 4 inches diameter. Graded bedding, large scale cross-bedding, and pebble layers common. Unit includes large red-brown calcareous concretions, which stand out as resistant boulders on grassy slopes. Described as Cachagua member of Chamisal Formation by Neel (1963). Thickness reported to be about 140 m (450 ft) (Neel, 1963). Deposits unconformably overlie crystalline basement rocks. Continental beds grade upward into moderately-sorted, medium-to fine-grained, buff to gray marine sandstone and well-sorted, light gray marine sandstone. Mapped by Durham (1970), and Dibblee (1972) in northern Santa Lucia range.
- M<sub>1</sub>b Basalt (Miocene?)**—Black basalt and olivine basalt with minor xenoliths of dark brown hornfels. Similar volcanics within Santa Margarita Sandstone north of the map area suggests a Miocene age (Graymer p.c. 2015) mapping by Dibblee (1971).
- M<sub>1</sub>r Rincon Shale (early Miocene to late Oligocene)**—Deeply weathered brown silty claystone contains sandy siltstone and gray to orange- colored calcareous beds or pods. Maximum thickness estimated to be 125 m (Hall, 1991). Mapped by Hall (1991) south of the Little Sur River.
- M<sub>1</sub>pbr Pinnacles Volcanic Formation, Breccia Member, white aphanitic rhyolite flows (early Miocene to late Oligocene)**—Layers within breccia and tuff unit, in part perlitic and autobrecciated. Matthews, (1973)
- M<sub>1</sub>pbb Pinnacles Volcanic Formation, Breccia Member, breccia and tuff (early Miocene to late Oligocene)**—Reddish brown breccia and tuff-breccia, includes lapilli-tuff and minor tuff. Layering defined by sparse erodible tuff layers within breccia. Indistinct layering within breccia typically indicates truncation and disruption of underlying beds. Clasts are poorly sorted and consist of massive and flow-banded rhyolite ranging in size from 0.01 mm to 3.5 m, averaging 2-8 cm. Thickness ranges from 220 to 320 m north of Pinnacles National Park to 500 to 800 m in the central Pinnacles area. Gradational contact with underlying tuff unit. Matthews, (1973)

- M<sub>1</sub>pbt Pinnacles Volcanic Formation, Breccia Member, predominantly tuff (early Miocene to late Oligocene)**—Includes breccia, tuff-breccia and lapilli tuff. Thin-bedded, cream colored. Graded bedding, rip-up clasts and dis-articulated ostracod fossils indicated deposition by turbidity currents. Matthews, (1973)
- M<sub>1</sub>ppr Pinnacles Volcanic Formation, Porphyritic Rhyolite Member (early Miocene to late Oligocene)**—Pale pink, porphyritic flow-banded rhyolite. Grayish pink to pale reddish purple aphanitic groundmass with sparse phenocrysts of plagioclase, quartz, and biotite. In part perlitic. Matthews, (1973)
- M<sub>1</sub>pd Pinnacles Volcanic Formation, Dacite Member (early Miocene to late Oligocene)**—Gray, with yellow-green and pale red porphyritic dacite flows and breccia. Gray aphanitic ground mass with conspicuous white phenocrysts of plagioclase up to 5 mm diameter. Forms several outcrop areas up to about 1 km length and 125 m width in a discontinuous belt. Outcrops may represent erosional remnants of one large flow or several flows. Matthews, (1973)
- M<sub>1</sub>pag Pinnacles Volcanic Formation, Agglomerate Member (early Miocene to late Oligocene)**—Heterolithologic, rounded boulders abundant near base. Individual beds and unit as a whole fines upwards. Pumiceous tuff beds near top. Beds near the base of the Agglomerate member contain boulders > 1 m in diameter. Boulders are generally rounded and composed of flow-banded rhyolite, andesite, dacite, granitic rocks, pegmatite and pumice-lapilli tuff. Erosional base of unit and large clasts suggest high energy deposition, probably as lahars. Thickness is reported to be from 0 to 70 m. Matthews, (1973)
- M<sub>1</sub>pa Pinnacles Volcanic Formation, Andesite Member (early Miocene to late Oligocene)**—Brown, black and red andesite flows. In part glassy. In part scoriaceous and autobrecciated. Matthews recognized three varieties of andesite which could not be mapped separately due to alteration and poor exposure: a hypocrystalline hypersthene andesite, an augite-olivine andesite, and an andesite tuff. The hypocrystalline hypersthene andesite described as porphyritic with a hyalopilitic groundmass. Phenocrysts are orthopyroxene, plagioclase, quartz and rare clinopyroxene. The augite-olivine andesite is locally amygdaloidal, with vesicles filled with chalcedony, quartz and more rarely zeolites. The tuff is monolithologic and associated with scoriaceous auto-brecciated andesite, leading Matthews to the interpretation that it represents the brecciated tops of andesite flows. Matthews, (1973)
- M<sub>1</sub>ppl Pinnacles Volcanic Formation, Pumice Lapilli Tuff Member (early Miocene to late Oligocene)**—White and greenish-gray thin-bedded pumice lapilli tuff. Bedding, including graded bedding locally apparent due to differential weathering. Consists largely of pumice fragments generally 2-3 mm in diameter, ranging up to 10 cm in maximum dimension, variable amount of 1 to 3 mm diameter lithic clasts of rhyolite. Forms resistant cliffs and ledges. Thickness is reported to be from 0 to 80 m. Matthews, (1973)
- M<sub>1</sub>prm Pinnacles Volcanic Formation, Rhyolite Member- massive rhyolite (early Miocene to late Oligocene)**—Very light gray to pale red, aphanitic with few small phenocrysts. Probably conformable contacts with underlying flow-banded rhyolite and overlying rhyolitic breccia members. Matthews, (1973)

- M<sub>1</sub>prp Pinnacles Volcanic Formation, Rhyolite Member-perlite (early Miocene to late Oligocene)**—Black to dusky green, non-porphyrific, flow-banded perlite, in part microbrecciated. Interpreted to be the hydrated, chilled top of the flow represented by the flow-banded rhyolite member. Possibly partially eroded before deposition of agglomerate member, thickness ranges from 0 to 70 m. Matthews, (1973)
- M<sub>1</sub>prf Pinnacles Volcanic Formation, Rhyolite Member-flow banded rhyolite (early Miocene to late Oligocene)**—Pale reddish-purple, yellowish gray, or grayish red on fresh surfaces, weathers with to pale yellowish orange, aphanitic, flow-banded rhyolite. In part microbrecciated, Thickness estimated to be between 700 and 1000 m. Matthews, (1973)
- M<sub>1</sub>prv Pinnacles Volcanic Formation, Rhyolite Member-vitric lapili tuff (early Miocene to late Oligocene)**—Black, perlitic tuff and gray pumiceous tuff. In part welded. Includes clasts of obsidian, pumice and lesser granitic rock. Thickness is reported to be from 30 to 140 m. Matthews, (1973)
- M<sub>1</sub>di Pinnacles Volcanic Formation, dikes (early Miocene to late Oligocene)**—Andesite, dacite and rhyolite dikes. One rhyolite dike has similar composition and texture as massive rhyolite described above (Matthews, 1971). Includes dacite, rhyolite and andesite dikes mapped by Andrews (1936) as modified by Dibblee (1971) within plutonic rocks surrounding Pinnacles volcanic center mapped by Matthews, (1973).
- M<sub>1</sub>Ost Temblor Formation (early Miocene to Oligocene)**—White to light gray arkosic sandstone, weathers buff, outcrops locally show cavernous weathering. Includes significant biotite, mudstone chips and siltstone rip-up clast up to 5 cm long. Described by Graymer (p.c. 2015) in fault sliver west of San Andreas Fault and shown as mapped on oil company file map (anonymous, ca 1930).
- M<sub>1</sub>O<sub>6</sub>vq Vaqueros Formation (early Miocene to Oligocene)**—Gray arkosic sandstone, thick-bedded to massive, cross-bedded, with minor conglomerate and mudstone interbeds, contains mollusk fossils. Fine-grained bioturbated sandstone with vertical burrowing in the upper parts of beds local coquina, and medium-grained, cross-bedded sandstone layers suggest deposition in an open marine shelf environment (Graham, 1976). Mapped in central Santa Lucia range, Dibblee (1971).
- O<sub>6</sub>va Basaltic andesite (Oligocene?)**—Vesicular andesite and breccia, very dark gray weathering to deep reddish brown. Mapped by Dickinson (unpublished) at Hastings Reserve in upper Carmel Valley, also crops out to the northwest between San Clemente and Las Garzas Creeks.
- O<sub>6</sub>be Berry Formation (Oligocene)**—Pale gray to pale yellow-brown arkosic sandstone and conglomerate. Thick-bedded to massive, with minor mudstone interbeds. Seiders, (1983). Absence of fossils and presence of cross-bedding, red beds and conglomerate suggest non-marine deposition (Graham, 1976). Mapped in Santa Lucia range south of Arroyo Seco (Seiders, 1983).
- E<sub>oc</sub>c Church Creek Formation (Eocene)**—Gray and gray-green silty mudstone; intercalated with poorly-sorted, soft, brown phosphatic and ferruginous siltstone and brown or tan fine- to medium-grained, calcareous, arkosic sandstone. Thin lenses of pebble and cobble

conglomerate in lower part of formation. Over 450 m (1500 ft) thick in Church Creek area. (Dickinson, 1965). Mapped in Santa Lucia range south of Arroyo Seco (Seiders, 1983).

- EoCS Church Creek Formation, sandstone member (Eocene)**—Lens of thick-bedded, medium-grained arkosic sandstone probably representing a filled submarine canyon. Up to 180 m (600 ft) thick in Church Creek area. (Dickinson, 1965) Also mapped in Santa Lucia range south of Arroyo Seco by Seiders (1983).
- Eotr The Rocks sandstone (middle and early Eocene)**—Gray, buff weathering, thick-bedded, fine- to coarse-grained, calcareous, arkosic sandstone. Includes mudstone interbeds and conglomerate. Local basal conglomerate, thicker where unit unconformably overlies crystalline rock. Resistant to weathering; forms local hogbacks and flatirons. 120 to 250 m (400 to 800 ft) thick in Church Creek area. Thick-bedded turbidite sandstone and bathyal foraminifera assemblages indicate a deep-sea fan depositional environment (Graham, 1976) Dickinson (1965), Seiders et al. (1983).
- Eol Lucia shale (early Eocene)**—Greenish gray, massive, bioturbated silty mudstone. Includes few sandstone interbeds representing turbidite deposits. Fine-grained deposits and bathyal foraminiferal assemblages indicate a basin-plain depositional environment (Graham, 1976). Up to 75 m (250 ft) thick in Church Creek area. Mapped by Dickinson (1965), Seiders, (1983), central Santa Lucia range.
- EoP<sub>tr</sub> Reliz Canyon Formation (middle Eocene to late Paleocene)**—Sandstone, generally yellow-brown, fine-grained, in beds a few cm to over a meter thick with interbeds of pale greenish-brown silty claystone and some conglomerate beds. Conglomerate includes well-rounded pebbles from 1-10 cm of a variety of igneous and metamorphic lithologies. Mapped by Seiders et al. (1983) in the Santa Lucia Range on the southwest side of Junipero Serra Peak. Probably correlates with Junipero Sandstone-Lucia Mudstone-The Rocks Sandstone sequence mapped on northeast side of Junipero Serra Peak.
- EoP<sub>tr</sub>c Reliz Canyon Formation, conglomerate beds (middle Eocene to late Paleocene)**—Pebble conglomerate with well-rounded 1-20 cm clasts of a wide variety of igneous and metamorphic lithologies. Medium gray fine to coarse-grained sand matrix. Mapped by Seiders et al. (1983) in the Santa Lucia Range on the southwest side of Junipero Serra Peak.
- EoP<sub>ej</sub> Junipero Sandstone (early Eocene to late Paleocene)**—Gray, coarse-grained, thick-bedded, pebbly arkosic sandstone. Massive, sandstone with local cross-bedding, burrows and coquina composed largely of mollusk shells deposited as a shallow-marine transgressive sand sheet (Graham, 1976) Up to 45 m (150 ft) thick in Church Creek area. Mapped by Dickinson (1965), Wiebe (1966), Dibblee, (1971) in the central Santa Lucia range.
- P<sub>tr</sub>sh Unnamed marine shale and sandstone (Paleocene)**—Dark gray, weathering to olive-brown silty mudstone with thin beds of micaceous fine sandstone and concretions to 30 cm diameter. Deeply weathered, does not form natural outcrops. Mapped by Seiders et al. (1983) and Dibblee (1974) in Santa Lucia range south of Arroyo Seco and west of Junipero Serra peak.
- P<sub>tr</sub>ss Unnamed marine sandstone (Paleocene)**—Light gray-brown, medium- to coarse-grained pebbly sandstone. Thick-bedded to massive. Forms prominent, nearly bare outcrops in central Santa Lucia range south of Arroyo Seco. Described as “Merle Formation” by Graham (1976).

Mapped by Seiders et al. (1983) and Dibblee (1974) in Santa Lucia range south of Arroyo Seco.

- R&c Carmelo Formation (Paleocene)**—Conglomerate composed of pebbles and cobbles in a sandy matrix with interbeds of sandstone. Mapped by Dibblee (1973) southeast of Carmel.
- Kss Unnamed marine sandstone (Late Cretaceous)**—Light gray brown, medium- to coarse-grained pebbly sandstone. Thick-bedded to massive. Large outcrop area in Santa Lucia range south of Arroyo Seco is conformable with overlying Paleocene sandstone. May have been deposited as turbidite sequence on high-relief erosional surface of Salinian Block basement (Ruetz, 1979). Similar appearing rocks described by as “Upper Cretaceous Sedimentary Rocks” by Hall (1991) are more structurally disrupted. Mapping by Dibblee (1974). Seiders et al. (1983), Hall (1991) includes isolated areas mapped as un-named marine clastic sedimentary units (KTg and KT<sub>s</sub>) by Dibblee (1971).
- Ksh Unnamed marine shale (Late Cretaceous)**—Dark gray silty claystone with interbedded arkosic sandstone and conglomerate. (Hall, 1991)

### Great Valley Complex

- Kgvsh Great Valley complex shale (Cretaceous, in part Jurassic?)**—Dark-colored silty claystone with interbedded sandstone and conglomerate. Found in the Diablo Range block, not in the Salinian block. Includes area mapped as upper Cretaceous Panoche formation by Dibblee (1971), Also mapped by Hall, (1991)
- Kgvs Great Valley complex sandstone and shale (Cretaceous, in part Jurassic?)**—Medium to coarse--grained, brown, well-bedded but sheared sandstone and shale. Weathers to pale gray-brown. Found in the Diablo Range block and the Nacimiento block (mainly south of the Point Sur 30’x60’ quadrangle), not in the Salinian block. Includes area mapped as lower Cretaceous Gravelly Flat formation by Dibblee (1971). Also mapped by Hall, (1991)
- Jsp Serpentinite (Jurassic)**—Light gray green to green intensely sheared and foliated serpentinite. Contains relatively unaltered peridotite or pyroxenite blocks. Crops out as fault-bounded bodies in the Diablo Range block, presumably part of the Coast Range ophiolite.

### Franciscan Complex

- KJfs Franciscan complex greywacke and shale (Jurassic? to Cretaceous)**—Fine to medium-grained sandstone composed of quartz and feldspar grains and sand-sized rock fragments with interbedded dark gray shale. Large blocks or “slabs” without significant internal shearing.
- KJf Franciscan complex greywacke and mélangé (Jurassic to Cretaceous)**—Fine to medium-grained sandstone composed of quartz and feldspar grains and sand-sized rock fragments with interbedded dark gray shale. Commonly pervasively sheared to mélangé: a matrix of sheared shale with blocks of greywacke, conglomerate, chert, greenschist, blueschist, and metavolcanic “greenstone”. Chert described as: Red, white and green thin-bedded chert, typically contorted and sheared. Greenschist: Hard, foliated, dark greenish gray schist found as blocks within mélangé. Blueschist: hard, foliated, dark bluish gray schist found as blocks

within mélangé. Metavolcanic “greenstone” as described below. Larger blocks are shown on original mapping by Hall (1991) but omitted from this map for clarity at 1:100,000 scale. Mapped blocks are included in digital database that accompanies map.

**KJfmv Franciscan Complex metavolcanic rocks (Jurassic to Cretaceous)**—Fine-grained hard, greenish gray metamorphosed volcanic rocks (typically basalt). Locally shows pillow structure from submarine eruption of basalt flows. Includes area mapped as meta-gabbro (Hall, 1991) and described as medium to coarse-grained, hard, greenish gray metamorphosed gabbro.

**Jsp Serpentinite (Jurassic to Cretaceous?)**—Light gray green to green intensely sheared and foliated serpentinite. Contains relatively unaltered peridotite or pyroxenite blocks. Where queried (Jsp?), includes isolated small blocks mapped by Ross (1976) along fault zones and within metamorphic rocks of the Salinian Block. Ross (1976) speculates that these are dominantly exotic to the Salinian Block, but that some may represent metamorphosed ultramafic rocks of the Salinian Block basement. Jsp mapped by Hall (1991), and Dibblee (1971).

### Salinian Complex Plutonic Basement

**Ka Aplite, alaskite, and pegmatite (Cretaceous)**—Light gray to pale brown, medium- to coarse-grained aplite, alaskite and pegmatite is found as widely distributed veins and small intrusions in the Gabilan Range (Ross, 1972). These rocks form a larger body west of Pinnacles.

**Kgdm Porphyritic Granodiorite of Monterey (Cretaceous)**—Light to medium gray, medium to coarse-grained granodiorite with distinctive phenocrysts of pink potassium feldspar up to 10 cm long. The unit is relatively homogeneous, but there is a considerable range in the ratio of plagioclase to K-feldspar based largely on the irregular distribution of phenocrysts (Ross, 1976). Unit is interpreted by Ross (1976) as probably an intrusion into the Granodiorite of Soberanes Point before that unit had entirely solidified, resulting in a mixed zone between the two units.

**Kgdc Granodiorite of Cachagua (Cretaceous)**—Light to dark gray, medium to coarse-grained, gradational unit between granodiorite of Monterey and quartz-diorite of Soberanes Point. Ross (1976) interprets exposures along Malpaso Creek as showing that the granodiorite of Monterey intruded the quartz diorite of Soberanes Point before the latter had solidified, resulting in a mixed zone between the two units. Mapped by Dibblee (1972), and Ross (1976).

**Kqds Hornblende-biotite quartz diorite of Soberanes Point (Cretaceous)**—Medium to dark gray, medium to coarse-grained, quartz diorite with abundant hornblende and biotite. Locally foliated with aligned diorite inclusions. Locally relatively rich in K-feldspar, approaching granodiorite in composition (Ross, 1976). Mapped by Wiebe 1966), Ross (1976), Clark and Rosenberg (1999).

**Kqmp Quartz monzonite of Pinyon Peak (Cretaceous)**—Felsic bodies of variable grain size and texture, in part alaskite and aplite, mapped in the Junipero Serra quadrangle. Many of the bodies are elongate and sill-like; numerous smaller masses of similar lithology, but too small

- to show at the scale of the map, are present throughout the northern Santa Lucia Range. According to Ross (1976) the circular outcrop in the Pinyon Peak area is typical of this unit. Ross (1976) interprets this unit as possibly the youngest in a sequence starting with the Bear Mountain and Junipero Serra Peak granodiorites. Similar rock also makes up the bulk of the granitic fraction of the abundant migmatitic rocks. Some of the rocks of the Big Pines and Island Mountain masses of Wiebe (1966) and the heterogeneous granitic complex of Wiebe (1966) may be correlative with the Pinyon Peak unit. Mapped by (Ross, 1976) and Seiders et al. (1983)
- Kgh Heterogenous granitic complex of Wiebe (1966) (Cretaceous)**—Undifferentiated, dominantly granitic rock mapped by Wiebe (1966) in areas with variable types of granitic rocks and insufficiently detailed mapping to show internal contacts. This unit is predominantly quartz monzonite and granodiorite and includes leucocratic quartz diorite, gabbro and diorite. Some metasedimentary rocks are included, but are estimated to make up less than 1 percent of the complex. The granitic complex is limited to the area mapped in detail by Wiebe (1966) with minor extensions by Ross (Wiebe, 1966; Ross, 1976); also includes some mapping by Seiders et al. (1983).
- Kqmv Variable Quartz monzonite–granodiorite of Big Pines and Island Mountain (Cretaceous)**—Medium to dark gray, medium to coarse-grained, quartz monzonite and granodiorite distinguished from surrounding rocks by absence of garnet. Mapped by Wiebe (1966), Ross (1976), Seiders et al. (1983), and Dibblee (1972).
- Kqdp Hornblende-biotite quartz diorite of the Paraiso-Paloma area (Cretaceous)**—Medium to dark gray, medium- to coarse-grained, quartz diorite with variable percentage and proportions of biotite and hornblende. Locally relatively rich in K-feldspar, approaching granodiorite in composition. The hornblende-biotite quartz diorite of the Paraiso-Paloma area extends for about 30 km along the west side of the schist of Sierra de Salinas. Ross (1976) interprets the form and position of the mass as suggesting that it may be intruded along a pre-granitic fault zone. The contact with the schist of Sierra de Salinas is generally very abrupt; locally there is a mixed zone across tens of meters where the schist is coarsened and contains hornblende. In contrast the Paraiso-Paloma rock is mixed migmatitically with the metamorphic rocks to the west over a broad and complex zone--the west contact is arbitrary. Ross (1976), Kidder (2006, unpub. mapping).
- Kqdc Hornblende-biotite quartz diorite- diorite of Corral de Tierra (Cretaceous)**—Dark gray, medium to coarse-grained, quartz diorite with 20-30% percent biotite and hornblende. Locally pegmatitic with hornblende crystals several centimeters long. Strongly foliated with slivers of schist near the contact of the northern mass with the schist of Sierra de Salinas. Interpreted by Ross as a local facies of the Paraiso-Paloma quartz diorite mass. An indistinct and arbitrary contact suggest mixing and gradation between the two units (Ross, 1976). Kidder (2006, unpub mapping).
- Kgdb Granodiorite- quartz diorite of Bear Mountain (Cretaceous)**—Dark gray hornblende-biotite quartz diorite mapped as separate bodies in the Junipero Serra Peak quadrangle (Ross, 1976). Locally gneissic. Resembles the Paraiso-Paloma quartz diorite as well as the quartz diorite of

Soberanes Point, suggesting that these may all be parts of one widely occurring plutonic formation (Ross, 1976) also includes mapping of Seiders et al. (1983).

- Kgdj Porphyritic Granodiorite of Junipero Serra Peak (Cretaceous)**—The porphyritic granodiorite of Junipero Serra Peak is described by Ross (1976) as partly gneissoid, with somewhat pinkish K-feldspar phenocrysts up to 15 mm long, but unlike the porphyritic granodiorite of Monterey. The unit occurs discontinuously along a narrow belt in the Junipero Serra quadrangle (Ross, 1976), includes mapping by Seiders et al. (1983).
- Kgdg Granodiorite of Gloria Road (Cretaceous)**—Light-colored, medium-grained granodiorite with biotite flecks. Seriate texture with K-feldspar phenocrysts to 15 cm. Locally includes magnetite, sphene, and allanite. Described by Ross (1972) in the Gabilan Range.
- Kgds Porphyritic Granodiorite of Sand Creek (Cretaceous)**—The Porphyritic Granodiorite of Sand Creek is described by Ross (1976) as characterized by distinctive salmon-pink K-feldspar phenocrysts as long as 30 mm, but more commonly 10 to 15 mm in largest dimension. Except for the presence of K-feldspar this rock closely resembles the Paraiso-Paloma unit. This unit disrupts the south end of the belt of outcrop of the Paraiso-Paloma unit, and could represent a gradational facies of the Paraiso-Paloma unit or a separate younger intrusive rock. Ross interprets the resemblance of the Sand Creek unit to the Junipero Serra Peak granodiorite, coupled with the resemblance of the Bear Mountain granodiorite and Paraiso-Paloma quartz diorite, as suggesting that these two pairs are correlative (Ross, 1976). Also includes mapping by Durham (1970) and Dibblee (1972).
- Kmi Gabbro and diorite in the Santa Lucia Range (Cretaceous)**—Small diorite and gabbro bodies within granitic and metamorphic units. Medium to coarse-grained, dark gray locally containing over 50% hornblende. Some areas are foliated, leading Ross (1976) to suspect that they are amphibolite, rather than of igneous origin. Mapped by Ross (1976), Seiders et al. (1983) and Dibblee (1971).
- Kqdg Gneissic quartz diorite of Stonewall Canyon (Cretaceous)**—Medium to coarse-grained quartz diorite. Light gray, weathering to light yellow-brown. Rich in biotite but poor in hornblende. Deeply weathered, forming deep gullies underlying most hillsides where it is mapped. Includes gneiss, locally migmatitic, and inclusions of schist and calc-hornfels (Ross, 1972).
- Kqdj Quartz diorite - granodiorite of Johnson Canyon (Cretaceous)**—Dark-colored, medium-grained rock with abundant mafic minerals including euhedral hornblende (Ross, 1972; Matthews, 1973).
- Kqmb Quartz monzonite of Bickmore Canyon (Cretaceous)**—Light colored, medium-grained quartz monzonite with variable amounts of biotite and distinctive pink K-feldspar phenocrysts. Includes minor amounts of muscovite, green hornblende and magnetite (Ross, 1972; Matthews, 1973; Dibblee, 1971).
- Kqml Garnetiferous quartz monzonite of Little Sur and South Ventana Cone (Cretaceous)**—Felsic bodies characterized by small red garnet crystals. The bodies are generally elongate and sill-like. Numerous garnet-bearing bodies too small to map and similar dikes and sills are in part related to this unit, but Ross (1976) notes that some garnet-bearing "sills" are really

metamorphic layers with rounded garnet eyes as large as 10 mm across. Mapped by Ross (1976) and Seiders et al. (1983)

**Kct Charnockitic tonalite (Cretaceous)**—Dark greenish gray, coarsely crystalline, slightly to highly foliated igneous rock composed predominantly of plagioclase, hornblende, orthopyroxene and related uraltic alteration products, and quartz in decreasing order of abundance. Minor amounts of K-feldspar, biotite, and metallic opaque minerals are also present. Red garnet is locally abundant. The larger area of this unit on the coast near Partington Canyon was studied by Compton (1960). Other areas to the southeast are described as "similar" by Compton (1960), but the igneous rock does not appear to contain orthopyroxene and does appear to have significant quantity of gneiss mixed with the granitic rock (Ross, 1976). An additional area that may correlate with the Charnockitic Tonalite east of Point Sur is similar in its low quartz content and presence of red garnet (Ross, 1976).

### Metamorphic Units of the Salinian Block

**Kms Schist of Sierra de Salinas (Cretaceous)**—Biotite quartzofeldspathic schist, layers of biotite a few grains in thickness alternate with quartz-feldspar layers generally less than 1 mm thick (Schombel, 1940). Lithologically distinct from the gneissic units in the surrounding Salinian Block. Lacks granitic inclusions, though it does contain quartz vein and minor pegmatite. The schist of Sierra de Salinas is the only predominantly schist unit in the Santa Lucia Range. Ross (1976) interprets the overall appearance and chemical composition as suggesting derivation from graywacke. Amphibolite metamorphic grade indicated by local red garnet and sillimanite as well as some coarse graphite. Ross (1976), Kidder (2006, unpub. mapping).

### Metamorphic units of the Salinian Complex

**MzPzc Coast Ridge belt (Mesozoic and/or Paleozoic)**—Quartzofeldspathic gneiss and granofels in an area west of the Palo Colorado and Coast Ridge faults and their possible extensions. Distinguished from other quartzofeldspathic metamorphic rocks by higher proportion of marble. Amphibolite is also relatively abundant. Hornfels and granofels appear to be generally less well banded than the gneissic rocks to the east. Impure quartzites and quartzofeldspathic granofels, and marble that contain coarse flakes of graphite, which Ross (1976) notes appears to be more widespread and possibly coarser than in the rocks to the east.

**MzPzgg Graphitic gneiss of the Coast Ridge belt (Mesozoic and/or Paleozoic)**—Calc-hornfels, and quartzofeldspathic gneiss distinguished by locally abundant graphite. Seiders (1983) mapped a belt of graphitic gneiss through the Coast Ridge belt.

**MzPzg Graphitic and Pyritic belt (Mesozoic and/or Paleozoic)**—Quartzite, calc-hornfels, and quartzofeldspathic gneiss distinguished by locally abundant black shiny graphite flakes. Pyrite is also locally common, leading to reddish weathered surfaces. Wiebe (1970b) also noted several thin lenses of conglomerate in this unit consisting of quartzite pebbles in a matrix. He interpreted the quartzite as a shallow water, quartz-rich deposit that was deposited in a reducing environment. Wiebe (1970) traced the graphitic and pyritic belt for more than 30 km, the most continuous lithologic marker mapped in the metamorphic section. Though the graphitic and pyritic belt is sharply defined, interfingering contacts can be seen with the

adjoining rocks, suggesting gradational contacts. Thin graphitic schist lenses are also found within the quartzofeldspathic rocks adjacent on the west. Mapped by Wiebe, (1970b) as the Los Padres unit.

**MzPzp Pelitic schist belt (Mesozoic and/or Paleozoic)**—Pelitic schist, Quartzofeldspathic gneiss, granofels and biotite-feldspar quartzites without graphite or abundant pyrite (Wiebe, 1970b). Gneiss and admixed granitic rocks are locally abundant in this unit, it appears to be derived from a more shaly part of the original sedimentary section (Ross, 1976). Ross also notes that the eastern contact is gradational into the quartzofeldspathic rocks.

**MzPzqf Quartzofeldspathic rocks (Mesozoic and/or Paleozoic)**—Quartzofeldspathic gneiss and granofels, with biotite-feldspar quartzite, and minor schist, marble, calc-hornfels, and amphibolite. These rocks are characteristically well banded with contrasting lithologies that commonly suggest an originally thin-bedded sedimentary parent rock. The quartzofeldspathic unit is essentially what is left over after all of the more distinct metamorphic units have been described separately. Described by Ross (1976) based on mapping by Ross, Compton (1966a) and Wiebe (1970a), includes rocks mapped as undifferentiated Sur Series by Weibe (1966) and undifferentiated schist, gneiss and quartzite by Dibblee (1974)

**MzPzms Mica schist (Mesozoic and/or Paleozoic)**—Quartzofeldspathic mica schist with minor calcareous rocks, amphibolite and quartzite. Mica schist composed of intermediate plagioclase, quartz, reddish-brown biotite, olive to green hornblende, and potassium feldspar. Muscovite is locally abundant. Amphibolite is generally hornblende with plagioclase and minor quartz. Mapped by Ross (1976) in the Gabilan Range.

**MzPzq Quartzite (Mesozoic and/or Paleozoic)**—Biotite-feldspar quartzite originally mapped by Compton (1966) as a continuous bed extending easterly for about 5 km north of Pinyon Peak. Generally fine-grained. Ross (1976) interprets the layer to be on the order of 150 to 300 m thick based on the map pattern shown by Compton (1966).

**MzPzm Marble (Mesozoic and/or Paleozoic)**—White coarsely crystalline marble to platy gray fine crystalline limestone. Some bodies are nearly pure calcite with minor quartz and graphite (Hart, 1966). Others are dolomitic and/or mixed with mixed with metamorphic and granitic rock. The marble is generally resistant to soil formation and erosion, so forms relatively bare gray to white outcrops. As noted by Ross (1976), size of many smaller bodies of marble are probably exaggerated on the map, but some extensive bodies do occur, especially in the Coast Ridge belt.

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